BAY AREA REGIONAL RAIL PLAN

Technical Memorandum 4e

Electrification of the Bay Area Regional Rail System
Cost, Issues and Potential

March 30, 2007

EarthTech
A tyco International Ltd. Company
Korve Engineering

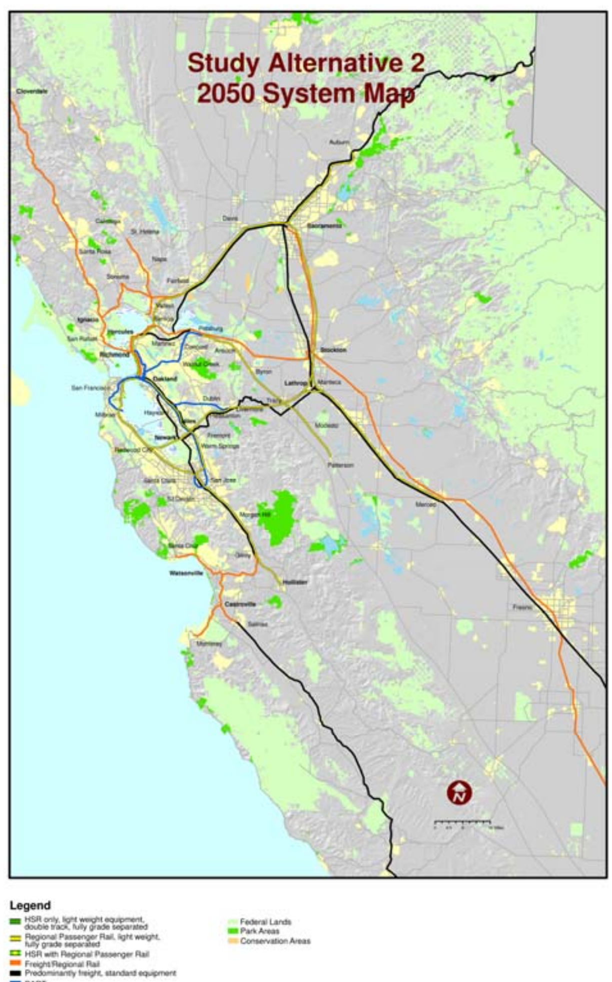
Scope of Work

CONSULTANT shall perform an evaluation of potential for railroad electrification under each of the study alternatives. The level of detail for this task to be commensurate with the budget and need to evaluate the merits of each alternative.

1. General - ELECTRIC JUSTIFICATION AND FUTURE POWER NEEDS

A key question is: Should all planned year 2050 rail system be electrified? Or should only selective rail segments be electrified? The corridors under consideration for electrification are shown on Alternative 2; yellow corridors. The alternatives under consideration are :

1. Study Alternative 1 - Expansion of existing operations; standard (compliant) passenger equipment alongside existing freight. Separate passenger and freight operations on high volume corridors. No electrification
2. Study Alternative 2 – Separate freight and passenger system using light weight (non-compliant) passenger equipment on high volume corridors.
3. Study Alternative 3 – High speed rail coming into the Bay Area from the east over the Altamont Pass and light weight (non-compliant) passenger equipment on this route and on other high volume corridors.
4. Study Alternative 4 – High speed rail coming into the Bay Area from the south over the Pacheco Pass and light weight (non-compliant) passenger equipment on this route and on other high volume corridors.



Only the corridors shown in Study Alternative 2 are under consideration. The corridors in Study Alternative 1 are all non-electrified and the High-speed rail corridors in Alternative 3 and 4 are all electrified and do not need to be evaluated.

If some or all lines are to be electrified, what will be the initial cost of installation and what will be the operational costs? Will the utility power supply grid be stiff enough to meet the power requirements of moving projected electrified trains at specified headways?

On rail system where double-stacked container freight vehicles are presently operating or are expected to operate in the future, electrification using an overhead contact system (OCS) wire will require further reviews to find possible solutions to the increased height of the contact/messenger wire above the tracks. The additional height of the OCS would introduce speed restrictions for the passenger vehicles for speeds higher than say 100 mph. It is also anticipated that the freight railroads would have general objections to having OCS on their right-of-way. Such restrictions require that the passenger rail and freight be separate and the corridors have been shown as such.

A dual system that uses OCS wire and switches to 3rd rail in tunnels and other restricted areas is possible but it may not be practical. The dual system requires a more cumbersome and consequently more expensive mixed design of the 3rd rail system and the OCS system. In addition, the combination of 3rd rail with OCS would introduce speed restrictions for speeds in excess of 80 mph which are needed for this project. Furthermore the dual system would require vehicle fitted with both types of power supply input from OCS as well as from 3rd rail which would create additional vehicle costs and maintenance issues. Thus the only recommendable viable option is to use OCS system. For purposes of this study a mixed system of OCS and 3rd rail has not been considered further; all corridors if electrified will be constructed using an OCS.

This study starts with the premise that the utility power supply grid will be augmented in the future and that it will be adequate to supply power for the trains by means of properly sized traction power substations located along the electrified rail tracks. It is also assumed that the future system will favor electrification rather than the use of other available fuels. Since air pollution and global warming issues must be confronted in the future; trains using conventional fuel such as diesel fuel may not be acceptable. Since liquefied natural gas (LNG) fuel also has its own drawbacks we feel that electric power has a better potential in the future for application to train systems. Both electric and LNG operation will require plans to generate the power required for train operations. To mitigate local pollution due to power generation, additional power plants can be located at remote sites, such as in the desert. In addition, the Federal Energy Commission and power utilities companies are aggressively pushing for green power generation technology, such as wind, solar, fuel cells, and tidal power to lessen the impact of air pollution generated by power plants. Modern train propulsion systems which incorporate electronics make electric power utilization for train propulsion much more efficient compared to past technology. Also, work is being done to implement future power transmission using high voltage power cables up to 230 KV. Public concern over additional transmission lines or line extensions to traction power substations may result in transmission lines for the train system being constructed underground to make them more acceptable.

Electric power undoubtedly will be more expensive in the future. Refer to the attached projected electric energy forecast, based upon the fuel market. This forecast was developed by Earth Tech team last year for Port of Long Beach electrical master planning study, specifically for power delivery by SCE. See table; **SP 15 Base Case Wholesale Electricity Prices** It is understood that there are many variables that could offset projected electrical power and energy costs, however such discussion is beyond the scope of this report. We believe that all BARERS will be under one agency and power supply metering, and billing should be on an integrated combo billing methodology. Such billing methodology not quite in favor of the power utility companies will require separate studies and legal interpretation of power delivery rules and regulations. However, with the use of such billing, the costs of demand and energy charges for the entire electrification system will be less compared to having individual billing meters at each traction power/facility substation. BART presently has specific negotiated direct access Time of Usage (TOU) tariff rates with PG&E, with all electricity meters totalized for one combined bill for PG&E power usage for the entire BART system. We expect that a similar billing methodology for the entire future rail electrification system will be used. All 115 kV power supply system as well as the 25 kV traction electrification systems will be specified to have a full Supervisory Control and Data Acquisition (SCADA) system for the purpose of monitoring, control and protection of the power supply system. Specific details of such SCADA system will needs to be developed when conceptual locations of power supply substations, switching stations are confirmed with additional refinement studies of this electrification system. It is a true statement that such SCADA system the present as well as the future trend of any type of power distribution system.

SP 15 Base Case Wholesale Electricity Prices

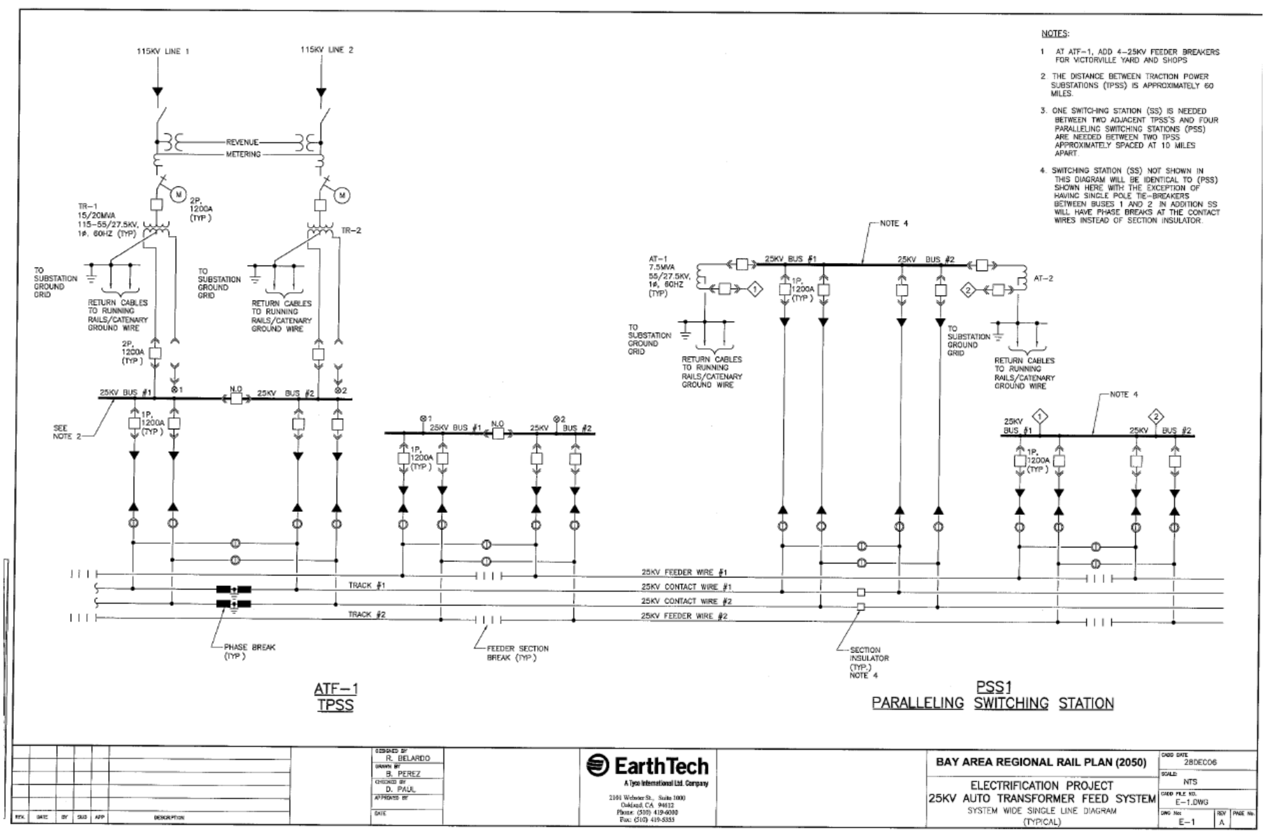
(1)	Year (2)	Avg On-Peak SP15 Price cents/kWh (3)	Avg Off-Peak SP15 Price cents/kWh (4)	Avg Baseload SP15 Price cents/kWh (5)
	2001	11.0	3.4	7.7
	2002	3.4	2.2	2.9
	2003	5.2	3.5	4.4
	2004	5.5	3.9	4.8
Historical	2005	7.3	5.2	6.4
Forecast	2006	7.4	4.0	5.96
	2007	9.8	5.2	**7.82**
	2008	10.9	5.8	8.71
	2009	10.5	5.7	8.47
	2010	10.4	5.6	8.33
	2011	10.1	5.4	8.08
	2012	10.2	5.4	8.12
	2013	10.3	5.4	8.17
	2014	10.3	5.4	8.21
	2015	10.4	5.4	8.26
	2016	10.4	5.5	8.30
	2017	10.5	5.5	8.35
	2018	10.5	5.5	8.40
	2019	10.6	5.6	8.45
	2020	10.7	5.6	8.50
	2021	10.9	5.7	8.67
	2022	11.3	5.9	8.99
	2023	11.7	6.1	9.31
	2024	12.2	6.4	9.68
	2025	12.7	6.6	10.09
	2026	13.0	6.8	10.33
	2027	13.3	7.0	10.58
	2028	13.6	7.1	10.83
	2029	13.9	7.3	11.08
	2030	14.2	7.5	11.35
	2031	14.3	7.5	11.41
	2032	14.4	7.6	11.47
	2033	14.5	7.6	11.54
	2034	14.6	7.6	11.61
	2035	14.7	7.7	11.67

2. INTRODUCTION TO ELECTRIFICATION

Railroad ac electrification projects world-wide now use one of two types of traction electrification systems based on many interrelated engineering considerations. These two types are as follows:

- Direct Center Feed System (DCF) operating at 25 kV ac electrification voltages, single-phase, at 50 Hz or 60 Hz, depending upon the commercial power supply frequency.
- Autotransformer Feed System (ATF) operating at 2x25 kV ac electrification voltages, single-phase, at 50 Hz or 60 Hz, depending upon the commercial power supply frequency.
- The United States uses commercial 60 Hz frequency. The present and future power supply system for the Bay Area Regional Electrified Rail System (BARERS) will receive power from the nearest utility grid transmission lines at 60 Hz, at a voltage level between 115 kV or 230 kV, suitable for the electrification substations. Appropriately rated substation transformers will be needed to transform the utility supply voltage to the 25/50 kV ac voltage level needed for the electrification system.

For this preliminary conceptual phase, we considered that the ATF electrification system would be more appropriate for all rail plans which are candidates for electrification system. Refer to the typical substation one line diagram Drawing E-1 (below) to provide an overview of the overall major traction power supply equipment that will be needed for the electrification of this passenger rail project.



The traction power equipment ratings shown are for a typical substation that we believe will be needed based upon our preliminary traction power requirements, shown on Table 1.

TABLE 1: ESTIMATED TRACTION POWER SYSTEM EQUIPMENT REQUIREMENTS		
Item No.	Description	Quantity
A - Traction Power Substation (TPSS)		
1	115 kV outdoor type, gang-operated, 2-pole, single throw, load break, manually operated disconnect switch, rated at 600 amperes minimum, 80,000 amperes momentary rating. The switch shall have a lockable handle to accommodate a utility company lock.	2
2	115 kV outdoor type, gang-operated, 2-pole, single throw, load break, motorized disconnect switch, rating same as in item 1 above.	2
3	115 kV manually operated grounding disconnect switch, outdoor type, and gang -operated 2-pole, single throw, and rated 600 amperes minimum (to be key -interlocked with item 2 above).	2
4	115 kV SF6 circuit breaker, outdoor type, 2-pole, rated 1200 amperes continuous (minimum), 63,000 amperes interrupting symmetrical, complete with necessary protective devices and meters. This switching equipment will act as the primary disconnecting and protection devices to the traction power transformer.	2
5	Traction power transformer, outdoor type, oil-insulated, rated at 15/20 MVA, OA/FA, (provisions with forced air cooling system), 115 kV – 25/50 kV, single phase, 60 Hertz. Transformer shall be equipped with automatic load tap changer and shall be complete with built-in protective devices and current transformers for all required protective relays. Lightning (surge) arresters shall be provided on the primary and secondary bushings of the power transformer.	2
6	Double-ended 25 kV, indoor-type switchgear, vacuum or SF6 circuit breaker consisting of two-pole main-tie-main and four single pole feeder breakers rated at 1200 amperes continuous, 40,000 amperes interrupting symmetrical. Each circuit breaker shall be complete with metering and relaying potential and current transformers, and specific protective relays for their operation under fault conditions.	1
7	25 kV vacuum or SF6 circuit breaker, single pole, four single-pole feeder breakers rated at 1200 amperes continuous, 40,000 amperes interrupting symmetrical. Each circuit breaker shall be complete with metering and relaying potential and current transformers, and specific protective relays for their operation under fault conditions.	1
8	Motorized disconnect switch, outdoor type, single-pole, 25 kV, 600 amperes, 40,000 amperes momentary rating. The	12

TABLE 1: ESTIMATED TRACTION POWER SYSTEM EQUIPMENT REQUIREMENTS		
Item No.	Description	Quantity
	disconnect switch shall be suitable for vertical mounting.	
9	Pre-packaged Control Building	1
10	Grounding # 4/0 AWG bare copper ground wire #250 kCMIL bare copper ground wire. Ground well including ¾" rod Ground rod, ¾" copper clad Exothermic welds	 750 ft. 1000 ft. 6 ea. 12 ea. 40 ea.
11	Power Cables 750 kCMIL, 46 kV, EPR shielded copper cable 250 kCMIL, 46 kV, EPR shielded copper cable	 1,000 ft 100 ft.
	Power and Control Conduits and Control Cables	1 lot
B - Paralleling Switching Station (PSS), or Switching Station (SS)		
1	Indoor type, 25 kV, vacuum or SF6 circuit breaker switchgear consisting of two (2) two-pole main breakers and eight (8) single pole feeder breakers, rated at 1,200 amperes continuous, 40,000 amperes interrupting symmetrical. Each circuit breaker shall be complete with metering and relaying potential and current transformers, and specific protective relays for their operation during fault conditions	1
2	Auto-transformer, outdoor type, oil-insulated, rated at 7.5 MVA OA, 25/50 kV, single phase, 60 HZ. Transformer shall be complete with built-in protective devices and current transformers for all required protective relays. Lightning (surge) arresters shall be provided on the high voltage terminal bushings of the transformer.	2
3	Motorized disconnect switch, outdoor type, single pole, 25 kV, 600 amperes, 40,000 amperes momentary rating. The disconnect switch shall be suitable for vertical mounting.	12
4	Pre-packaged Control Building	1
5	Grounding # 4/0 AWG bare copper ground wire #250 kCMIL bare copper ground wire Ground well, including ¾" rod Ground rod, ¾" copper clad Exothermic welds	 750 ft 1000 ft 6 ea 8 ea 30 ea
6	Power Cables - 250 kCMIL, 46 kV, EPR shielded copper cable	800 ft
7	Power and Control Conduits and Control Cables	1 lot
C - 115 kV Supporting Structures and Concrete Foundations for each Traction Power Substation (TPSS)		
1	Concrete foundations	1lot
2	Structural steel	1lot
3	2" IPS tube, aluminum, including fittings	1lot

TABLE 1: ESTIMATED TRACTION POWER SYSTEM EQUIPMENT REQUIREMENTS		
Item No.	Description	Quantity
4	Chain link fences and gates	1lot
5	Utility transmission line extension to TPSS	1lot
D - 25 kV Supporting Structures and Concrete Foundations for each paralleling stations (PSS) or each switching station(SS)		
1	Concrete footing	1lot
2	Structural steel	1lot
3	2" IPS tube, aluminum including fittings	1lot
4	Chain link fences and gates	1lot

The above list is a partial list of the items. For unit prices of various elements of the cost, please refer to the conceptual, rough order-of magnitude cost estimate contained in Appendix 1 of this report. The exact number of substations on each rail track will vary depending upon the length of the track.

Our initial search of the electric utilities' existing transmission lines close to the proposed Bay Area passenger rail system revealed that there are existing overhead transmission lines with voltage ratings of 500 kV, 230 kV, and 115 kV transmission lines. With the future commercial development we expect that the power supply grid will develop many tap feeders making 115 kV or 230 kV lines connecting rail traction power substations feasible and relatively short. There are three major power companies relevant to this project: Pacific Gas and Electric Company (PG&E) covering the Bay Area, with transmission lines connected to Bonneville Power Administration (BPA) in the north, and connected to Southern California Edison (SCE) Company transmission lines in the south. Refer to attached Figure 1 for presently existing transmission lines, power plants, substations and electric service territories in western USA.

Any one of the power supply voltages indicated above can be tapped and converted to 25/50 kV ac power for the project. However, we recommend that the preferred primary power supply of 115 kV ac should be used for the traction power substations. For initial cost estimation purposes we used 115 kV as the supply voltage to all traction power substations on all rail lines.

Figure 1

Transmission Lines, Power Plants, Substations and Electric Service Territories in Western USA

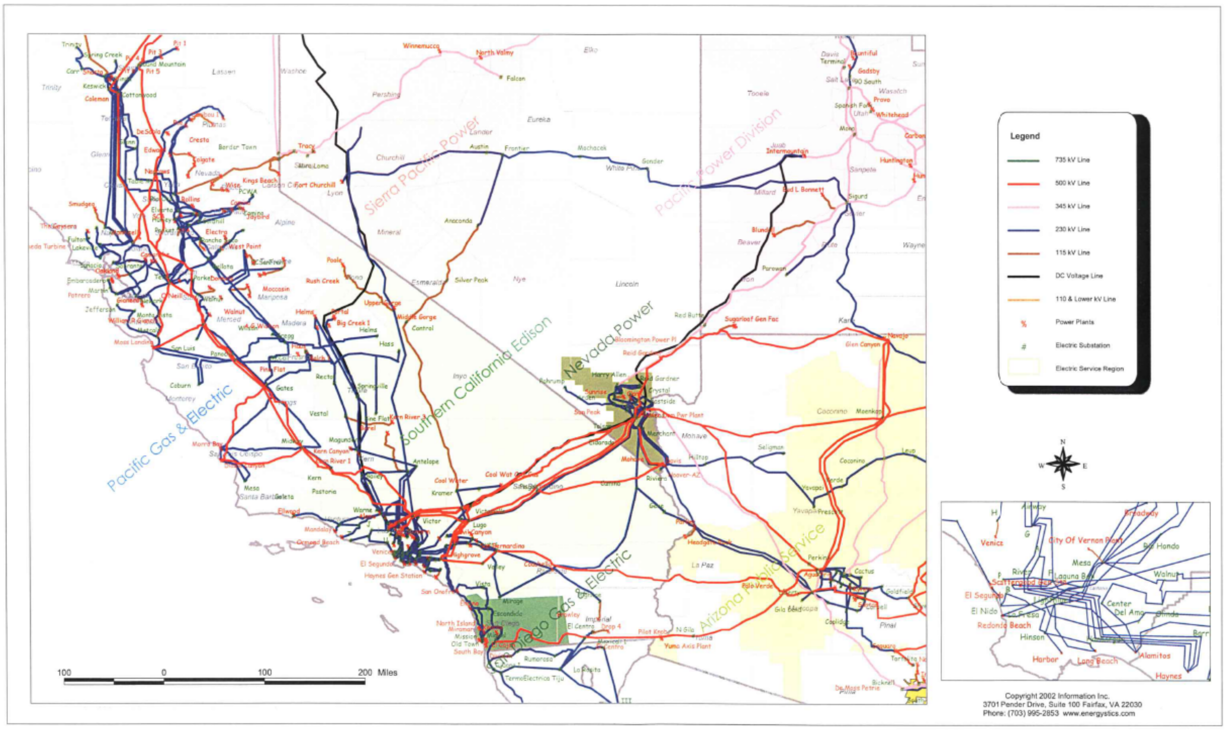
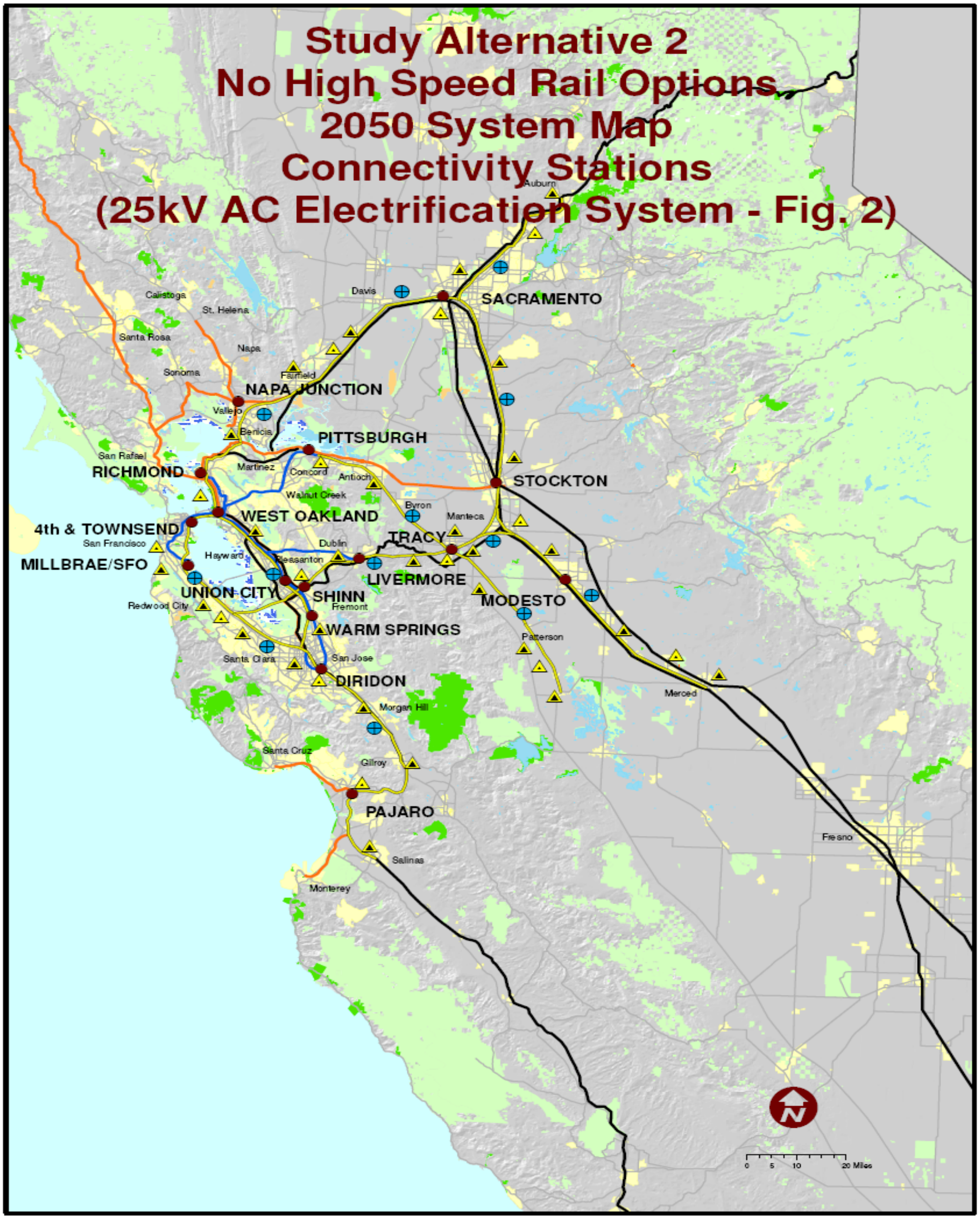


Figure **1**

3. BASIC ELECTRIFICATION SYSTEM – PARAMETERS

The conceptual traction power supply system requirements indicated in this document are based on the following parameters:

- Approximate track miles of each double track rail system for electrification purposes as indicated in Table 2
- Average train speed 125 to 150 miles an hour
- Limited number of train stops as shown on in technical memorandum 4a and included on (25kv AC Electrification System - Fig.2).
- Two maintenance facilities and control facilities perhaps one close to Manteca and another in West Oakland area. All SCADA system control for the electrification system can be centralized from these two locations.
- For 10-car train operation (2 power cars and 8 trailer cars per consist), the power requirements (kwh/car-mile), which includes on-board train auxiliary power and the train propulsion power has been considered for the initial power supply estimate.
- Kwh/car-mile data has been developed by comparing this system with similar systems that we have worked on in the past. For this conceptual system the number of train starts and stops is limited because on many of the track segments stations are located at ends of lines only. Therefore, the kwh/car-mile for this system should be relatively small compared to systems with greater numbers of train stops.
- Auto transformers with a 2:1 ratio capable of providing 27.5 kV voltages between the contact wire and the running rails, and 55 kV voltages between the feeder wire and the contact wire under no load conditions have been used.
- A simple catenaries auto tensioning termination for the OCS system. For additional OCS system descriptions see Section 5.



Legend

- HSR only, light weight equipment, double track, fully grade separated
- Regional Passenger Rail, light weight, fully grade separated - 25kV AC Electrified System
- HSR with Regional Passenger Rail
- Freight/Regional Rail
- Predominantly freight, standard equipment
- BART
- Federal Lands
- Park Areas
- Conservation Areas
- Traction Power Substation (TPSS)
- Parallel Switching Station (PSS)
- Switching Station (SS)

4. TRACTION POWER SYSTEM

Each traction power substation (TPSS) will be equipped with two 15/20 MVA oil-cooled transformers that will step down the utility supply voltage of 115 kV to the 27.5/55 kV distribution voltage. The Auto-Transformer Feed System will require the installation of traction power substations, spaced approximately 60 miles apart. In addition, there will be one auto-transformer switching station and four intermediate auto-transformer paralleling switching stations between the adjacent traction power substations equally spaced approximately 10 miles apart. The switching stations and paralleling switching stations will be equipped with two 7.5 MVA oil-filled auto-transformer units. Pole-mounted 25 kV parallel feeders will be installed throughout the route in support of each catenary. The current flow in the parallel feeders is generally in the opposite direction to that in the catenaries conductors and, as a consequence, tends to cancel the electro-magnetic interference (EMI) effects created by the main catenaries. See Table 1 for estimated number of traction power substations (TPSS) and parallel switching stations (PSS) on each rail segment. Some of these TPSS and PSS will become common to specific rail segments as seen in Figure 2

As shown in the typical single line diagram Drawing E-1, the two parallel overhead 25 kV feeders are connected to the two 25 kV catenaries wire systems to supply power via autotransformers located at the TPSS and at the paralleling stations. Parallel feeders and catenaries will be designed as completely separated electrical circuits, although they will share the same common supporting structures, including the OCS poles.

Each feeder and catenaries circuit is equipped with its own single pole circuit breakers, and all circuit breakers are equipped with a full complement of protective relaying. The circuit breakers operate independently and different protective relaying can be used for the feeder and catenaries circuits, based upon the power system protection criteria established during the next phase of the study. Once the parallel feeders and catenaries wires are sized adequately for the train operation under normal and abnormal operating conditions, the feeder and catenaries circuits can be energized, de-energized, and tripped independently of each other. Following a catenaries circuit fault, only the faulted section of the catenaries between sectioning points will be automatically tripped. All other feeder and catenaries circuits will remain in service.

The substation autotransformer primary (115 kV) and secondary side (25 kV) switching and protective devices will be two-pole circuit breakers. Likewise, the autotransformer's switching and protective devices at the paralleling stations will be two-pole 25 kV circuit breakers.

The single-phase traction power transformer primary windings will be connected to two phases of the utility power supply system and, for this configuration, since power is drawn from only two phases of a three-phase system, a certain amount of voltage and current unbalance will occur on the utility supply system. To mitigate the effects of such unbalanced current and voltage, the phase-phase connections at the utility system should be altered at successive traction power transformers. Additionally, to minimize this problem of unbalanced load on the utility system, each traction power substation is recommended to consist of two identical transformers instead of using a single transformer with higher ratings.

Remote terminal units (RTU's) at each of the traction power substations and each of the paralleling stations will communicate with the central Supervisory Control and Data Acquisition (SCADA) system for control and monitoring of the entire traction electrification system.

The traction power substation ratings are based upon an estimated value of the number of kwhs/car-mile using basic parameters we know for typical expected rail vehicles we expect to operate in the system. Preliminary estimated traction power substation rating shown in this report should be analyzed in next phase of the study when more definite criteria of the vehicles as well operating headways and track geometry is know. For such future power system analysis can be performed by using software used for developing train voltage profiles, maximum power peak demands for short intervals, such as 1 minute, and 15 minutes, and the average power demand for two hours using actual track grades, track curvature and speed restrictions. It is possible that there may be a need for end-of-the-line paralleling switching stations with one auto-transformer, depending upon the location of train stations and the end traction power substation contingency outage conditions, which may not be reflected in our estimated TPSS, SS and PSS indicated in table 1 and 2. Analysis in next phase of the study can be performed once definitive locations of the stations are established with respect to end-of-the-line tracks.

5. OVERHEAD CONTACT SYSTEM (OCS)

Two types of overhead contact system (OCS) will be used for the Regional Rail electrification infrastructure. Single Catenary Auto-Tensioned (SCAT) OCS will be used where trains will travel on mainline at-grade, on retained-cut, on embankment, on elevated structure, on bridges and at stations. SCAT system lines will be divided into approximately 1 mile tension sections, with sections overlapping each other to maintain the continuity of power collection. Counterweights used at both ends of the tension section are applied to keep the tension of the contact and messenger wire constant as the wire temperature increases and decreases. The contact wire is anchored at the line midpoint to keep the cross-track movement of the cantilever arms on both sides approximately equal. A 4/0 AWG, hard drawn (HD) copper, grooved, contact wire and a 4/0 AWG, hard drawn (HD) copper, stranded, messenger wire with the same equivalent Aluminum Cable Steel Reinforced (ACSR) parallel feeder per track along with associated connecting hardware will be used. The wires will be supported by cantilever arms attached to traction electrification system (TES) poles.

In addition to feeder, messenger, and contact wires indicated above, a dedicated 2/0 AWG ground/static wire has also been included in the OCS system. The ground/static wire improves train voltage, minimizes un-desirable rail-to-ground potentials, and acts as a lightning shield wire to protect the OCS system from the unpredictable threat of lightning strikes.

For double track configuration, TES poles can be installed in the center of the two tracks with two cantilever arms projecting towards the center line of each track to support the track messenger/contact wire/feeder wire/static wire of each track. This arrangement of center pole is usually possible when both tracks levels are relatively equal. Approximately 30 center TES poles are needed for each tension section, or about 30 poles per mile. For double track with side poles, the number of TES poles will be doubled to 60 per mile. Although common center poles for both outbound and inbound OCS system is possible, however, an additional studies are needed when each segment of the tracks are evaluated with closer look where separate side poles may be needed for specific reasons. The height of the wire will normally vary from 19’ to 25’ depending on the types of trains using the track and on obstructions based on AREMA. The gradient of the wire, changing from one height to another, will have to be maintained at 0.1% for speeds of above 150 miles per hour. TES poles can be round, hollow, tapered, galvanized steel, or wide-flange galvanized steel. TES pole foundation types will be drilled pier cast-in-place concrete, bridge/elevated structure concrete deck, or concrete pilaster. At locations where a TPSS feeds power to the OCS, section insulator/phase break will be utilized to separate two feeding sections.

Single Wire Fixed-Termination (SWFT) will be used inside tunnels, long cut-and-cover areas, and yards and shops. Supplemental feeder will have to be installed in embedded conduits in the roof of the tunnel or cut-and-cover structure. The OCS wire supports in the tunnel and cut-and-cover will be located 15’ to 30’ apart depending on the speed of train and alignment of the track. A 4/0 AWG, hard drawn (HD) copper, grooved, contact wire and a 500 kCMIL, 46 kV, EPR shielded copper cable feeder will be used for SWFT. In maintenance yards the feeder will run in conduits below ground. Connections from the feeder to the single contact wire must be made at equal intervals. In maintenance yards the OCS wire(s) will be supported 100’ to 120’ apart by cantilever arms, cross spans or gantries depending on track spacing. TES poles in the yard will be round, hollow, tapered, and galvanized steel. TES pole foundations will be drilled pier cast-in-place concrete.

6. LIST OF MAJOR TRACTION POWER EQUIPMENTS

The cost estimate is based on the types of major power supply equipment required for a typical traction power substation (TPSS) and a typical parallel switching station (PSS).

The list of the major equipment required for one (1) 115 kV TPSS interfacing between the utility company's incoming high voltage feeders and 25 kV power supply feeders up to the track overhead contact wires, feeder wires and the track running rails is listed below. The list below also includes the electrical equipment needed for a typical PSS.

It should be noted that a there will be some transmission line extensions of various lengths between the power utility company transmission lines and the traction power substations. Exact length, tap locations and routing is the subject of a follow up studies on this rail electrification system, however, for cost estimation purposes we made an appropriate allowance in this report.

TABLE 2: 25 KV AC ELECTRIFICATION SYSTEM COMPONENTS AND COST

Item No.	Track Segment Description[1]	Segment Length (Miles)	Segment Total OCS Cost & Elect. Equipment	
			OCS Cost[2] 1,000($)	Traction Power System Components[3] (For unit cost of TPSS, SSand PSS see Appendix 1 of this report)
1	4. Sacramento To Oakland	86		[4]TPSS = 3 [5]PSS= 6 [5]SS=2 For121 Track Miles from Auburn to Oakland
	4a. Sacramento To Martinez	56	72,000	
	4b. Martinez To Oakland	30	39,000	
2	5. Auburn To Sacramento	35	23,400	
3	7. Lathrop To Martinez	58		TPSS = 2 PSS = 2 SS = 1 Total Track Miles 58
	7a. Lathrop To Tracy	10	13,000	
	7b. Tracy To Antioch	30	39,000	
	7c. Antioch To Martinez	18	15,600	
4	8. Sacramento To Merced	114		TPSS = 3, PSS = 6, SS=2 See Below[6] See below[7]
	8a. Sacramento To Stockton	48	62,400	
	8b. Stockton To Merced	66	85,800	
5	10a. Niles Jct. To Stockton	63	81,900	See below[8], TPSS= 2, PSS = 4, SS=1 Equip. will be the same for 10a or 10b
	10b. Niles Jct. To Tracy	42	54,600	
6	11. Oakland To San Jose	65		See below[9] ,TPSS=2, PSS=4, SS=1

[1] Refer to Technical Memorandum 4a, for numbering system to the rail tracks

[2] OCS cost is based upon average capital cost of $1.3 Million/mile as of Year 2006

[3] Refer to Attached drawing E-2 for conceptual TPSS locations, and Table -2 for description of major equipments

[4] Traction Power Substation (TPSS)

[5] Paralleling Switching Station (PSS), Switching Station (SS)

[6] Three alternative tracks 8a, 8b and 8c which are candidates for electrifications system will require practically equal electrification system equipment components.

[7] Both alternative tracks 8e and 8d will result in equal electrification system equipment components

[8] For electrification cost estimation purposes, we consider distance indicated in 10a

[9] For electrification purposes, this section is a candidate for commuter rail electrification as well as for high speed rail system. 25 kV ac electrification infrastructures should be planned to meet power requirements for both systems by common electrifications components.

	11a. Elmhurst To Diridon	34	44,200	See below[10] , Elect. Equipment for tracks between Oakland & San Jose will not change for any combination of tracks indicated in Tech. Memo 4a.
	11b. W. Oakland To Newark	31	40,300	
	11c. Melrose To Niles Jct,	20	26,000	
7	12. San Francisco To San Jose	47	61,100	See below[11], TPSS = 2, PSS = 6, SS = 1
	10a. San Jose to Gilroy	30	39,000	See Below[12] TPSS = 1, PSS = 2
	10b. Gilroy to Salinas	38	49,400	
8	13. Redwood Jct. To Newark	11	14,300	Will need TPSS on each end
9	9. Tracy To Los Banos	57	74,100	TPSS = 2, PSS = 6, SS=1

[10] These alternative track routes as listed here and taken from technical memorandum 4a, and basically cover the electrification system components under Item 6 (Oakland to San Jose)
[11] See technical memorandum 4d for general overview and discussion of the tracks.
[12] This section of the track electrification will be extension of the system under Item 6 or Item 7

APPENDIX 1

Unit Prices for Cost Estimation

Rough order of magnitude of the cost of each typical TPSS, PSS, SS and main line tracks OCS poles and associated infrastructures installed cost is indicated below.

Quantities referred and used in the estimate is on conceptual basis. This equipment count and associated costs when studied with additional refined electrification studies with phased early year's electrification system could lower initial cost of electrification system. In addition, better picture of the major equipment/ratings as well as substation spacing on each electrification line segment can only be determined by power system analysis. Such analysis is recommended in the future version of such reports.

Cost is based upon December 2006 dollars and no escalation has been applied.

TABLE 3

Item No	Description	Estimated Quantities	Estimated Cost Sub-Total
A -Typical Traction Power Substation Components			
1 thru 11	See Table 1 for description	See Table 1 for description and quantities	$7,100,000
B- Typical Parallel Switching Station (PSS) or Switching Station (SS)			
1 thru 7	See Table 1 for description	See Table 1 for description and quantities	$3,640,000
C- 115 kV Structures & Site work for a Typical TPSS			
1 thru 7	See Table 1 for description	See Table 1 for description and quantities	$1,400.000
D- 25 kV Structures & and concrete foundation for a Typical PSS, or Typical SS, or Typical TPSS			
1 thru 7	See Table 1 for description	See Table 1 for description and quantities	$450,000
Main line tracks OCS Cost per mile			
See Table 2	See Table 2	See Table 2	$1,300,000 /mile

Appendix 2

Natural Gas and Electricity Price Forecasts

The following table shows the planning team projected natural gas prices delivered to electric generators in Southern California for low, base and high cases.

TABLE 4: Natural Gas Prices Delivered to Electric Generators in Southern California

Year	Low Case Delivered Price	Base Case Gas Price Forecast (nominal $ per MMBtu)	High Case Delivered Price
2006	6.73	6.73	6.73
2007	7.24	8.51	8.51
2008	7.09	9.37	9.63
2009	6.80	9.08	10.34
2010	6.40	8.93	10.70
2011	6.00	8.53	11.06
2012	6.00	8.54	11.07
2013	6.01	8.54	11.08
2014	6.01	8.55	11.08
2015	6.02	8.55	11.09
2016	6.03	8.56	11.09
2017	6.03	8.57	11.10
2018	6.04	8.57	11.11
2019	6.04	8.58	11.11
2020	5.78	8.58	10.84
2021	6.22	8.75	11.29
2022	6.59	9.12	11.66
2023	6.95	9.49	12.02
2024	7.39	9.93	12.46
2025	7.88	10.41	12.94
2026	8.13	10.67	13.20
2027	8.39	10.93	13.46
2028	8.66	11.19	13.73
2029	8.93	11.47	14.00
2030	9.21	11.75	14.28

The table **SP 15 Base Case Wholesale Electricity Prices** shows historic and forecast electricity prices for on-peak and off-peak periods in SP 15. These zonal prices form the basis for projecting the costs of wholesale purchases. In addition, these prices (with various adjustments for the load shape) are used in this report's forecast of SCE's long-term tariffs.

In 2001, the second year of the California energy crisis, electricity prices were relatively high and averaged 7.7 cents/kWh. Then prices collapsed to 2.9 cents/kWh in 2002, because of lower natural gas prices, more hydro generation and new plants coming on-line. Prices rose through 2005. The forecast average price for 2006 at 5.64 cents/kWh is lower than 2005, primarily because of lower natural gas prices and better hydro conditions. However, 2006 supplies were barely adequate in Southern California. As supplies tighten with increasing load growth, the risks of shortages and price spikes will increase.